

# Quantum Non-Objectivity from Performativity of Quantum Phenomena

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## Abstract

We analyze the logical foundations of quantum mechanics (QM) by stressing non-objectivity of quantum observables which is a consequence of the absence of logical atoms in QM. We argue that the matter of quantum non-objectivity is that, on the one hand, the formalism of QM constructed as a mathematical theory is self-consistent, but, on the other hand, quantum phenomena as results of experimenter's performances are not self-consistent. This self-inconsistency is an effect of that the language of QM differs much from the language of human performances. The first is the language of a mathematical theory which uses some Aristotelian and Russellian assumptions (e.g., the assumption that there are logical atoms). The second language consists of performative propositions which are self-inconsistent only from the viewpoint of conventional mathematical theory, but they satisfy another logic which is non-Aristotelian. Hence, the representation of quantum reality in linguistic terms may be different: from a mathematical theory to a logic of performative propositions. To solve quantum self-inconsistency, we apply the formalism of non-classical self-referent logics.

keywords: non-objectivity of quantum observables, logical structure of quantum description, self-inconsistency, self-referent logic, photon existence,

Grangier-type experiments, coefficient of second order coherence, prequantum classical statistical field theory, *Physarum polycephalum*

## 1 Introduction

At many occasions, Niels Bohr repeated that quantum mechanics (QM) does not yield a description of objective reality; in particular, the values of quantum observables cannot be assigned before measurement (they are not properties of objects) [1]: “There is no quantum world. There is only an abstract quantum physical description. It is wrong to think that the task of physics is to find out how Nature is. Physics concerns what we can say about Nature.”<sup>1</sup>

Non-objectivity of quantum observables<sup>2</sup> has tremendous consequences for the physical picture of micro-phenomena. It is not easy (if possible at all) to imagine lawful nature without objective properties of physical systems. Therefore, the idea that non-objectivity implies that at the microlevel the universe is totally lawless is a very common consequence of non-objectivity. Although the interpretation of the quantum universe as the totally lawless universe is very popular<sup>3</sup>, many experts in quantum foundations including even “quantum orthodoxes”, i.e., those who can not even imagine to go beyond quantum theory, feel unsatisfactoriness by appealing to the picture of the lawless universe for so lawful formalism as QM. Unfortunately, the only way to escape lawlessness is to appeal to quantum nonlocality: to claim that quantum observables are objective, but there is action at a distance. At the same time by the aforementioned reason, i.e., unwilling to go beyond QM, “quantum orthodoxes” do not like Bohmian mechanics. This situation

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<sup>1</sup>As is typical for the Bohr’s writings, the meaning of this statement is not clear. Did he deny the reality of quantum systems – atoms, electrons, photons? (The discussion in the present paper is essentially about the nature of photon. Here we remark that initially Bohr was critical to Einstein’s idea about quanta of the electromagnetic field. However, after the 1920s he, in fact, accepted Einstein’s idea.)

<sup>2</sup>Here we have to be very careful with the terminological issue. Bohr definitely did not consider quantum observables as properties of objects, quantum systems. Thus, from this point of view they are non-objective. At the same time, since for him measurement is performed by classical macroscopic devices, the result of measurement is objective as the output of a classical device. This problem, whether Bohr is for/contra realism, was analyzed in very detail by A. Plotnitsky, see [2], [3].

<sup>3</sup>Among the most active advertisers of this picture, we can mention, e.g., Anton Zeilinger [4], [5], whose theoretical considerations are supported by the incredible experimental research in quantum foundations. He and Caslav Brukner wrote a series of papers [6]–[8] on *irreducible quantum randomness*. (We remark that the idea that quantum randomness differs crucially from classical randomness was discussed already by von Neumann[9].)

is definitely self-contradictory.

First of all, we repeat our arguments from [10] supporting non-objectivity of quantum observables. Theoretically, the origin of non-objectivity was well explained by Bohr who pointed that the contribution of a measurement device into the result of measurement is *irreducible*.<sup>4</sup> Moreover, recent experiments on *quantum contextuality*, see [11], can be definitely interpreted as supporting non-objectivity of quantum observables; in any event there is no even a trace of nonlocality. Thus, if one is not really addicted on nonlocality, one cannot ignore that non-objectivity is the most fundamental feature of quantum phenomena.

What is the source of non-objectivity? Operationally, as was pointed by Bohr [1], it is the contribution of a measurement device to the result of measurement. However, such an operational explanation does not imply the logical justification of non-objectivity.

In this paper, we argue that the matter of quantum non-objectivity is that, on the one hand, the formalism of QM constructed as a mathematical theory is self-consistent, but, on the other hand, quantum phenomena as results of experimenter's performances are not self-consistent. This self-inconsistency is an effect of that the language of QM differs much from the language of human performances. The first is the language of a mathematical theory which uses some Aristotelian and Russellian assumptions (e.g., the assumption that there are logical atoms). The second language consists of performative propositions which are self-inconsistent only from the viewpoint of conventional mathematical theory, but they satisfy another logic which is non-Aristotelian. Hence, the representation of quantum reality in linguistic terms may be different: from a mathematical theory to a logic of performative propositions. At the level of mathematical theory, we deal with linguistic terms, satisfying the Aristotelian assumptions. At the level of logic of experimenter's performances, we deal with linguistic terms, not satisfying the Aristotelian assumptions.

Thus, we aim to avoid the "quantum inconsistency" by applying modern tools of symbolic logic for studying intelligent behavior (performances) and we will show that the quantum behavior satisfies all the basic properties of performances. Logical tools for studying human behavior were first proposed in the 20th-century language philosophy. Notice that in philosophy of language since Ludwig Wittgenstein [12], John Searle [13], and John Langshaw Austin [14] the ideas of non-objectivity of our everyday reality

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<sup>4</sup>It is very common to speak about *irreducible quantum randomness* [9], [4]–[8]. However, it is very difficult, if possible at all, to define irreducible randomness in mathematical terms.

have actively developed within the so-called paradigm of *linguistic solipsism* (cf. with aforementioned views of Bohr, von Weizsäcker, Brukner, Zeilinger). According to this paradigm, we deal just with linguistic reality if we think or act and cannot go out of language and return to things themselves. Any fact is seeable and understandable if and only if this is speakable and the fact can be described in a language [15]. So, in any thinking we are limited by our possible speech acts and in any activity by speech interactions. Language is a part of our behavior and the way we are interacting with others, for example by commanding, requesting, pleading, joking, debating, etc. Philosophers of language distinguish performative propositions designating and expressing our behavior from informative propositions denoting facts. While the *informative propositions* are truth-functions of the elementary propositions whose meanings are presented by facts, therefore they always have references in the real world, the *performative propositions* are non-objective in principle, we cannot find out any real references for them. They are self-referent and their meanings are just their utterances [12], [14]. In this paper, we will show that *some quantum statements should be considered as performative propositions, as well*.

By emphasizing the role of performative propositions in QM, we cannot avoid a discussion on the role of *free will*. We will show that in QM the problem of free will is involved in considerations – how quantum performances can be thought and treated as appropriate performative propositions for which there are no real references, because they (as well as performative propositions about human interactions) have a non-objective status.

The logical formalism for studying performative propositions was proposed in [16], [17]. In *Physarum Chip Project: Growing Computers From Slime Mould* [18] supported by FP7, we are going to implement this formalism among others to build up a programmable amorphous biological computer. In this computer, logic circuits are presented by programmable behaviors of *Physarum polycephalum*. Notice that *Physarum polycephalum* is a one-cell organism that behaves according to different stimuli called attractants and repellents and can be considered the basic medium of simple actions that are intelligent in the human meaning [19]–[24]. This biological computer has some properties of quantum computer, in particular we can perform the double-slit experiment for *Physarum polycephalum* to show that logical basics of *Physarum* behaviors are the same as logical basics of quantum behaviors. This means that we face performativity, non-objectivity, and self-referentiality not only in human interactions, but also in QM [25] and in the behavior of simplest biological organisms (see also [26] for quantum(-like) models of gene expression).

## 2 Self-inconsistency of verification of quantum mechanics: the principles of complementarity and individual-collective duality

Typically, discussions on self-inconsistency of QM are based on the principle of complementarity. We briefly present the most clear analysis of this problem, complementarity and self-inconsistency of QM, presented by C. Brukner and A. Zeilinger [29]. They pointed that N. Bohr [1] emphasized that “How far the [quantum] phenomena transcend the scope of classical physical explanation, the account of all evidence must be expressed in classical terms. The argument is simply that by the word ‘experiment’ we refer to a situation where we can tell others what we have done and what we have learned and that, therefore, the account of the experimental arrangement and the result of observation must be expressed in unambiguous language with suitable application of the terminology of classical physics.” Then, they remarked that rigorously speaking a system is nothing else, than a construct based on a complete list of propositions together with their truth values. For a quantum system, it can happen that the two propositions are mutually exclusive. This is a specific case of quantum complementarity. Therefore, in an attempt to describe quantum phenomena we are unavoidably put in the following situation. On the one hand, the epistemological structure applied has to be inherited from the classical physics: the description of a quantum system has to be represented by the propositions which are used in the description of a classical system with the Aristotelian semantics, and, on the other hand, those propositions cannot be assigned to a quantum system simultaneously. Now, a natural question arises: How to join these two, seemingly inconsistent, requirements?

In this paper we show that the problem of self-inconsistency of QM is even deeper, than self-inconsistency implied by the principle of complementarity. The essence of quantum self-inconsistency can be better characterized by the principle of the *individual-collective duality* which can be observed in the *Physarum* behaviour as well (for more details about this logic see [16], [17]): there are no logical atoms and something that seems a logical atom (e.g., an individual behavior) is in fact a family of other sets (e.g., a collective behavior, see section 8).

For example, let us define truth-valuations of QM conventionally, in the way of Aristotle and Russell:

- (i) the property  $E$  is actual (true) in a given state  $S$ , whenever a test of  $E$  on any physical object  $x$  in  $S$  would show that  $E(x)$  is true for every  $x$  in the state  $S$ ;

- (ii) the property  $E$  is nonactual (false) in a given state  $S$  whenever a complementary property  $\neg E$  on any physical object  $x$  in  $S$  would show that  $\neg E(x)$  is true for every  $x$  in the state  $S$ .

Objects  $x$  are interpreted as individuals (logical atoms). Assume that  $x$  mean quanta,  $E$ ,  $\neg E$  properties, discovered in the double-slit experiment, with the following meanings:

$E :=$  “the non-detection of the position of  $x$  on the first screen in one of the two slits and the detection of the position of  $x$  on the registration screen corresponding to the momentum representation with the interference picture”;

$\neg E :=$  “the detection of the position of  $x$  on the first screen in one of the two slits or the non-detection of the position of  $x$  on the registration screen corresponding to the momentum representation with the interference picture”.

According to the double-slit tests, we face that  $E(x)$  and  $\neg E(x)$  are true for the same state  $S$ . Obviously, that is self-inconsistent.

But we *can deny our assumptions that  $x$  are logical atoms*, i.e., we can assume that  $x$  are not exclusive individuals. For instance, we can put forward the following self-referent definition of  $x$ :  $\{x\} = \{a, b\}$ , i.e.,  $x$  is both  $a$  and  $b$ , where  $a = (b, (a))$  and  $b = (a, (b))$ , i.e.,  $a = (b(a(b(a(b\dots))))))$  and  $b = (a(b(a(b(a\dots))))))$  are two mutually depended infinite streams. Let  $E(a)$  be true,  $\neg E(b)$  be true,  $E(b)$  be false, and  $\neg E(a)$  be false. In this case,  $E(x)$  and  $\neg E(x)$  are true for the same state  $S$  and we cannot logically divide  $x$  into  $a$  and  $b$ , because  $x$  is a simple object, although it is not an individual. In this paper, we will show, how we can deal with these strange non-Aristotelian objects logically.

In our paper, we are limited just by an observational language. Notice that the language of any physical theory consists of two different languages: a theoretical language (formal theory with axioms and inference rules) and an observational language (semantics for the theoretical language). The first language contains theoretical terms, which are understood as expressions that refer to nonobservable entities or properties. The second language contains observational terms (observables).

A logic for observables is constructed in the observational language and a logic for theoretical entities in the theoretical language. In the early 20th century, there was a philosophical movement of logicism and its followers claimed that it is possible to construct a general logic for both observables and theoretical terms. This general logic could be called “logical physics”. It is a part of logic, where logical properties of terms and propositions in relation

to space, time, motion, causality, etc. are studied [27]. Usually, logical physics has been presented by logical tools for reducing propositions with theoretical entities to propositions with observables. In the accordance with this task, the theoretical terms are understood as follows: a term  $t$  is theoretical if and only if it holds, for all methods  $m$  of determining its extension, that  $m$  rests upon some axioms of some theory  $T$  and otherwise it is observational [28]. For example, in classical mechanics all methods of determining the force acting upon a particle appeal to some axioms of classical mechanics (CM), therefore force is a theoretical term for CM. The entity of spatial distance does not depend upon the Newtonian axioms. Hence, it is an observable of CM. Thus, the reduction procedure, which eliminates theoretical terms of an axiomatic theory by means of observables, is considered a set of semantic rules for interpreting propositions with theoretical terms on propositions with observables.

In the way proposed by R. Carnap and C.-O. Hempel, we can reduce theoretical entities by the following schemata:  $c \Rightarrow (h \Rightarrow e)$ , where  $h$  is a proposition in theoretical terms (hypothesis),  $c$  and  $e$  are propositions in terms of observables such that  $c$  expresses certain observational conditions, which are satisfied,  $e$  presents suitable detecting devices, which then have to show observable responses.

It was proven that there are ever theoretical terms which cannot be reduced to observational terms by any logical schemata. This circumstance of the existence of irreducible theoretical terms shows the rigorous limits of logical physics and logicism in physical sciences at all. For example, in QM there are, first, a formal physical theory formulated in a theoretical language and, second, its semantics formulated in an observational language describing quantum experiments. There is also a logical way to reduce theoretical entities to observables. This way is presented by quantum logic (QL). Its logical schemas of reduction are as follows:

$$p, q := \text{'observable } o \text{ has a value in a Borel set } \Delta'$$

and such propositions are represented by closed subspaces of a Hilbert space,  $\mathcal{H}$ . The set of all such subspaces forms an ortholattice,  $\mathcal{L}(\mathcal{H})$ , with  $p \leq q$  defined by ' $p$  is a subspace of  $q$ '. The logical operations of 'and', 'or', and 'not' are modelled respectively by the operations of meet (infimum), join (supremum) and orthocomplement on  $\mathcal{L}(\mathcal{H})$ . The lattice  $\mathcal{L}(\mathcal{H})$  is atomistic, complete, and orthomodular (non-distributive).

So, as we see, another concept of truth is defined in QL and this concept is radically different from the classical (Aristotelian-Russelian) concept of truth [30], because the QL schemas of reducing theoretical terms are different a lot

from the Carnap and Hempel's classical manner. The main problem of QL is that even in non-classical means of interpreting QM there are irreducible theoretical statements. For example, the QM explanations of the double-slit experiment cannot be directly interpreted in QL. Nevertheless, "quantum logics can be interpreted as a pragmatic language of pragmatically decidable assertive formulas, which formalize statements about physical systems that are empirically justified or unjustified in the framework of QM. According to this interpretation, QL formalizes properties of the metalinguistic concept of empirical justification within QM rather than properties of a quantum concept of truth" [30], see also Garola et al. [31],[32] and Rosinger [33]. The Garola's pragmatic extension of QL allows him to define justifications of theoretical statements which cannot be reduced directly, e.g., within this extension it is possible to justify the QM explanations of the double-slit experiment. We can remember that the irreducibility of theoretic entities can imply even scientific anarchism: "Science is an essentially anarchic enterprise: theoretical anarchism is more humanitarian and more likely to encourage progress than its law-and-order alternatives" [34]. Therefore, the pragmatic approach can explicate many presuppositions of quantum physicists and their way of reasoning as one of the possible ways.

Our approach to QL is different from the conventional QL with propositions defined on members of  $\mathcal{L}(\mathcal{H})$  and the Garola's pragmatic extension of this QL. First of all, we would like to follow the pure logicism that has been re-animated by unconventional computing recently. In unconventional computing, we appeal to the following schemata of logical reductions:  $I \Rightarrow (h \Rightarrow O)$ , where  $h$  is a theoretical proposition,  $I$  are inputs of an unconventional computer (quantum computer, DNA-computer, *Physarum polycephalum* computer, etc.) and  $O$  are outputs of this computer. In these schemata,  $h$  is interpreted as a processor of suitable unconventional computer.

Unconventional computing is not so ambitious as physical theories such as QM. This new approach to computations completely ignores theoretical entities if they cannot be applied in designing an appropriate unconventional (abstract or real) processor. Hence, it deals just with reducible theoretical terms. In our research, we found out that the behavioral logic constructed on the observables of *Physarum polycephalum* and parasites of Schistosomatidae (Trematoda: Digenea) can be directly applied in the double-slit experiment with quanta. The basic idea of this behavioral logic is in the individual-collective dualism that there are no logical atoms in behaviors. Notice that logical theories for unconventional computing are always constructed in an observational language. In our opinion, the propagation of photons has some similarities with an intelligent propagation of *Physarum polycephalum* [22], parasites of Schistosomatidae (Trematoda: Digenea) [23], and may other living organisms. Perhaps, we can claim about a new version of pantheism



and idealism that the same patterns of intelligent behaviors are observed everywhere – from quanta to one-cell organisms and human beings.

### 3 Self-inconsistency of verification of theoretical viewpoints on photon

Quantum optics (as a theoretical formalism) is based on the well-defined and self-consistent notion of photon. In order to couple the theory with experiments (i.e., to verify theoretical terms, to reduce them to observables), we need an operational definition of photon which can be coupled to its theoretical definition – as an excitation of quantum electromagnetic field. Operationally, we can define photon as a click of a photo-detector (e.g., A. Zeilinger, A. Migdall, S. Polyakov, private discussions). The main point of our discussion is that such a notion is not self-consistent in the Aristotelian-Russellian meaning (it has no sense in their semantics). Although nobody did tell about self-inconsistency of the photon-click definition, the problem is known (in other terms) and it can be called the problem of the *existence of photon*. In other words, it is the problem of verifying our theoretical viewpoints on photon. The basic experiment on the “existence of photon” was performed by Grangier [35],[36], see [37] for reviews on the present experimental situation; see also [38]–[41] for related experimental studies.<sup>5</sup>

The ideal experiment can be described as follows. There is a single photon source, beam splitter and two detectors, in each channel of splitter. If “photons really exist”, i.e., quantum electromagnetic field cannot be represented as a classical electromagnetic wave continuously propagating in space-time, then only one of two detectors has to click. This click can be identified with the presence of photon in this concrete detector.

We remark that this experiment is a special realization of the two slit experiment in “particle context”, i.e., the experiment in which both slits are open, but two detectors are in work: one behind each slit. The claim that only one of these detectors clicks (for a single photon source) was considered by Bohr as justification of the *principle of complementarity* – in combination with the experiment in which both slits are also open, but without the detectors behind the slits. The later experiment represents the wave-like interference behavior. Thus, the Grangier type experiment on the “existence

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<sup>5</sup>Formally, the aim of such experiments is to show an experimental incompatibility of semiclassical optics with quantum optics. However, from the foundational viewpoint experimenters really confront the problem of the existence of photon. The classical wave can be split by beam splitter, but photon not. Hence, by checking such a splitting one compares the classical electromagnetic field model with the quantum systems model.

of photon” is of the fundamental value for quantum foundations. We shall propose a new interpretation of the experiments of such type.

We point to the well-accepted experimental fact that one can never expect that the coincidence clicks (i.e., happening simultaneously in both detectors) will never occur. There are always the coincidence clicks and there are many such clicks. Therefore it was decided to count not the absolute number of coincidence clicks, but the relative number which is given by the coefficient of *second order coherence*  $g^{(2)}(0)$ ; the number of coincidences divided by the product of numbers of singles (i.e., at each of detectors). In principle, one is fine by getting that  $g^{(2)}(0) < 1$ . Such a result was used to reject semiclassical field theories. However, in real experiments  $g^{(2)}(0)$  is still relatively large (see sections 7, 9 for details) and *the claim that photon exists, in the operational sense as the click of a detector, is not justified.*

In such a situation, the operational (and hence experimentally verifiable) notion of photon cannot be considered as self-consistent. Any pair of coincidence clicks, for detectors  $D_1$  and  $D_2$ , can be interpreted as that two mutually complementary events,  $A_1$ , photon in  $D_1$ , and  $A_2$ , photon in  $D_2$ , happened simultaneously. However, logically  $A_1$  is negation of  $A_2$ . Thus, *at the level of the real phenomena, the theoretical term ‘photon’ of QM is not verified, moreover it is self-inconsistent on observables.* In our opinion, a possible explanation is that the observables for the photon notion are subordinated to performative regularities of some behavioral entities. And appropriate propositions in observational terms are not factual, but performative.

Hence, it would be better simply to recognize this fundamental self-inconsistency and irreducibility of some theoretical terms on the observables if we appeal to conventional logic and to try to proceed towards development of a new quantum theory which would not be based on the conventional logical tools, including classical QL. The modern development of information and computer science provides such a possibility. However, in the 1920s self-consistency of a mathematical theory in the meaning of classical logic was a fundamental requirement. Therefore, the self-consistent mathematical theory was created to describe physical phenomena, even if there is no way to reduce theoretical terms self-consistently. Heuristically, self-consistency can be considered as a sign of objectivity, a quantum event is either firmly true or false. Obviously, then, as Bohr pointed out, this is only objectivity of observed phenomena within verifications of a physical theory, i.e., not “real objectivity” which was discussed in the Introduction. Nevertheless, in this situation heuristically one wants to have some “elements of reality”. In our opinion, the self-consistency of the QM formalism is a main source of the permanent psychological drama in quantum foundations: reflections towards objectivity (in various forms, including nonlocal realism which is rather pop-

ular nowadays).

We can summarize the discussion of this section as follows: *Some experiments on the photon existence and on the irreducible deviation of the coefficient of second order coherence from zero have demonstrated that the operational notion of photon is not self-consistent on observables. This circumstance suggests us to construct a new mathematical formalism for quantum phenomena, which would be based on a logical system permitting behavioral entities which are performative and self-referent. Usage of the present mathematical formalism of QM (which is self-consistent) will permanently induce the illusion of a possibility of objective interpretation of QM.*

## 4 Non-objectivity from the viewpoint of self-inconsistency on observables

Let us consider the measurement of photon's polarization. Suppose that polarization is the objective property of photon. Thus, the result of the polarization measurement coincides with this objective property which was predetermined before measurement. However, the presence of the coincidence clicks and the corresponding self-inconsistency of the definition of polarizations up and down, for the setting  $\theta$  of the polarization beam splitter, puts a statistical constraint on this objectivity. Let us consider representation of the quantum state  $\Psi$  used for measurement by an ensemble of systems which is denoted by  $\Omega$ . For the setting  $\theta$ , let us denote the ensemble of systems (a subensemble of  $\Omega$ ) producing the coincidence clicks by the symbol  $\Omega_\theta$ . Hence, the self-consistent definition of the property of polarization in the direction  $\theta$  is possible only on the subensemble  $\bar{\Omega}_\theta = \Omega \setminus \Omega_\theta = \{\omega \in \Omega : \omega \notin \Omega_\theta\}$ , the complement to  $\Omega_\theta$ . Therefore, the vector of polarization can be objectively (and consistently) defined only on the subensemble  $\tilde{\Omega} \equiv \Omega \setminus \bigcup_\theta \Omega_\theta = \bigcap_\theta \bar{\Omega}_\theta$ . Of course, for each fixed  $\theta$ , the probability of the coincidence clicks is very small,  $P(\Omega_\theta) = \epsilon \ll 1$ .<sup>6</sup> However, the probability of the union  $\bigcup_\theta \Omega_\theta$  can be close to one. (In the complementary terms, although  $P(\bar{\Omega}_\theta) \approx 1$ , it can happen that the probability  $P(\tilde{\Omega}) = P(\bigcap_\theta \bar{\Omega}_\theta) \approx 0$ .) Thus, the self-inconsistency of polarization's observable in the form of the presence of coincidence clicks can restrict the possibility of the objective definition of polarization to a very small subensemble of systems prepared in the state  $\Psi$ .

The logical possibility that the “objectification subensemble”  $\tilde{\Omega}$ , can have

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<sup>6</sup>We emphasize that in any real experimental setup, although this probability is small, it has nonzero low bound:  $P(\Omega_\theta) \geq \epsilon_{\min} > 0$ , see sections 7, 9.

approximately zero probability<sup>7</sup>, makes the project of objectification of quantum observables questionable. In the light of the previous consideration, the appearance of non-objectivity in QM is not so surprising. Hence, if one has doubts in quantum non-objectivity, he has to find strong reasons for this.

However, in principle, to the question of objectification we need not proceed under the aforementioned assumption that elements of  $\bigcup_{\theta} \Omega_{\theta}$  form a representative sample (or in complementary terms that the objectification subensemble  $\tilde{\Omega}$  is a non-representative sample). In order to destroy objectification, it is sufficient to use the experimentally justified assumption that the probability of each  $\Omega_{\theta}$  is sufficiently far from zero:  $P(\Omega_{\theta}) = \epsilon$ , where one can take  $\epsilon \approx 0,03$  for sources producing photons on demand, see section 9. In such a situation, we cannot proceed with objective polarization, simply because we do not know whether for the coming trial the result will self-consistent or not. We may get a single click in one of channels, but we also may get coincidence clicks.

We may summarize the results of our analysis of the inter-relation of (non-)objectivity of quantum observables and their self-(in)consistency from the classical viewpoint in the following way: *The self-inconsistency of reducing theoretical entities of QM to **performative descriptions** of quantum observables makes really impossible the objectification of QM observables. (The procedure of objectification with some probability definitely contradicts to the standard views on objective reality.)*

## 5 Self-inconsistency contra elements of reality of Einstein, Podolsky, and Rosen

The Einstein, Podolsky, and Rosen (EPR) argument based on the consideration of elements of reality corresponding to quantum observables measured for some specially prepared states [42] (which are nowadays known as entangled states) is one of the strongest motivations for attempts of the objective interpretation of quantum observables. For example, in his considerations leading to Bell's inequality, Bell pointed that there is the strong reason to consider quantum observables as objective, precisely because of the EPR-argument [43]. The EPR-derivation of the possibility to assign to quantum systems in some states the objective values of two incompatible quantum observables was criticized in [45] from the viewpoint of usage of Lüders projection postulate in the case of observables with degenerate spec-

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<sup>7</sup>To be more rigorous, one has to speak about the probability to draw a system from the objectification subensemble  $\tilde{\Omega}$ .

trum, instead of the von Neumann original postulate. Now, we try to destroy the EPR-argument by using self-inconsistency argument of performances on observables.

Again, as in section 4, we can decrease the probability of objectification in the EPR-experiment by considering families of incompatible quantum observables. However, as was pointed in the previous section, for our purpose we need not proceed in such a way. Even for the fixed observable, we cannot predict, whether the result of the coming trial would permit the objectification or not. (Here we discuss the quantum optics version of the EPR-experiment, in which the projections of the photon polarization on different axes play the role of the original EPR-observables, position and momentum.)

The latter argument shows that the essence of the objectification problem is not in the presence of incompatible quantum observables.

Now in the light of our approach, we can remember the Bohr's reply to the EPR-argument [47]. Bohr stressed that even for one fixed setting one is not able to assign the element of reality to the first component of a compound system on the basis of the result of measurement on the second component. Thus, he also pointed that the problem arose already in the case of a single observable. His conclusion matches very well with our conclusion (although Bohr did not paid attention to self-inconsistency of theoretical terms on quantum observables).

## 6 Free will (performativity) against self-inconsistency

Various “technicalities” (see, e.g., the discussion below) play important roles in quantum experiments. These technicalities are not presented in the mathematical formalism of QM. Therefore, the real outputs of experiments deviate from the theoretical predictions based on straightforward mathematical computations. Taking these technicalities into account is a difficult problem. (In fact, it can be treated as a part of the quantum measurement problem.) Nevertheless, we can pay attention that some basic elements of these technical issues of the design of concrete experiments can be considered self-referent performative propositions. We illustrate this situation by consideration of quantum optics experiments.

All quantum optics measurements are fundamentally based on the proper choice of the *discrimination threshold*. It is a kind of performance that allows us to understand quantum phenomena. For our argument, it is very important to remark that the setting of the sufficiently high discrimination

threshold is an important part of experiments on “photon existence”, otherwise the  $g^{(2)}(0)$  coefficient would be too large; see the Grangier’s PhD-thesis [35]: “[...] In this configuration, the threshold has a double role of acquisition of timing information and of selection of the pulses (the too weak pulses are not taken into account). [...] We have in the present experiment chosen a **rather high threshold**, which amount to give the priority of the stability of the counting rates and the reproducibility of the results, rather than to the global detection efficiencies.” (We stressed with bold the important fact that Grangier proceeded with rather high threshold.) Thus, in our terms the selection of the discrimination threshold plays the fundamental role in minimization of self-inconsistency of reductions to quantum observables.

Evidently, the standard interpretation of this choice of the discrimination threshold is that this is the noise minimization procedure. However, if one uses the operational definition of photon as a click of a detector, i.e., if one studies the real quantum phenomena and not just theorizing, then there is a problem of separation of “noisy photons” from “real photons”, since both types are just clicks of detectors.

By putting the discrimination threshold, we insert a subjective element in all quantum optics measurement schemes. This insertion is based on our *free will* – to minimize self-inconsistency of QM (more concretely, self-inconsistency of the operational definition of photon as detector’s click) by appropriate performances. This is a complex psychological play. First, the scientists created a self-consistent mathematical representation of quantum phenomena. Then, they confronted the problem of coupling of theory with experiments. This is really a shadowed area of QM. One would not find so much material on coupling of theoretical entities of QM with *real experiments*. Typically, one is completely fine by repeating the Bohr’s statement that in some experimental contexts photons exhibit particle features. What is the experimental reality to be a particle, for photon? It seems that this important problem is practically ignored in theoretical studies on quantum foundations. However, experimenters have to solve this problem in everyday life. They do not discuss it in the papers presenting results of experiments, and majority simply ignores it. However, foundation-thinking experimenters understand the importance of this problem and each of them solves it for himself; and surprisingly, the solution is the same: experimentally, photon is nothing else than the detector’s click. However, by our interpretation experiments (of Grangier’s type) showed that this operational definition of photon is not self-consistent within classical QL. Again by our interpretation, an experimenter minimizes self-inconsistency with the aid of his free will.

Of course, if one considers free will as just a mental illusion and uses the picture of the totally deterministic universe, see K. Svozil [48] for the

detailed analysis of such a position, also cf. G.'t Hooft [49], then nature by itself minimizes self-inconsistency in the quantum phenomena. However, our analysis showed that even nature would not be able beat self-inconsistency completely: it has to respect the statistical constraint based on the presence of the coincidence clicks.

We also point to usage of another subjective element in minimizing self-inconsistency of coupling of quantum observables (as elements of the mathematical model of quantum mechanics) with real experiment. This is selection of the time window for identification of the clicks in the two channels of a beam splitter as the coincidence clicks. The coefficient  $g^{(2)}(0)$  fundamentally depends on this time window. Here again free will plays an important role. This is a performance type element of QM. The size of the time window is determined subjectively aiming to reproduce predictions of the QM mathematical model. We remark that the role of a proper selection of time window was discussed in very details in connection with the Bell type tests, see [50]–[52], [45]. This is well known coincidence time loophole for these test. In this paper, we point out that the same problem arises not only in experiments with entangled photons, but even in single photon experiments.

In general without subjective determination of “technicalities” such as thresholds and time widows, an experimenter is not able to approach even approximately matching with the QM theoretical formalism. Notice that these “technicalities” are not elements of mathematical formalism of QM.

We could summarize the discussion on free will, performativity, and self-(in)consistency of QM as follows: *Experimenter’s free will plays the crucial role in the improvement of self-inconsistency of quantum observables. Selections of proper values of various “experimental technicalities” can be interpreted as attempting to lower self-inconsistency of QM presented in usage of performance type statements in establishing coupling between theory and experiment. Not doing it intentionally, experimenters construct performative propositions for which there is another, non-Aristotelian logic.*

## 7 Experiments on “photon existence”

It is well known that photomultipliers and silicon-avalanche-photodiodes have low efficiency: an essential part of the ensemble  $\Omega$  of quantum systems representing some quantum state, say  $\Psi$ , disappears without any click. The presence of the “no-detection” event also contributes to self-inconsistency of theoretical terms on quantum physical phenomena. For some setting  $\theta$ , the two events,  $A_1$  – “polarization up” and  $A_2$  – “polarization down”, are considered as complementary and appearance of the third even,  $A_3$  – “no

detection”, destroys self-consistency on quantum observations, even in the absence of coincidence clicks. Therefore, from the very beginning we have considered the experiments on “photon existence”, on estimation of the coefficient of second order coherence, which were done with detectors of low efficiency as just dimming the problem of self-(in)consistency of quantum entities due to the presence of the coincidence clicks.

We are interested in experiments of the aforementioned type for detectors of very high efficiency, for TES-detectors. Theoretically they have 100% efficiency.

However, the main problem is even not in the detectors inefficiency. The main problem is that in reality *there are no pure single photon sources*:

“An ideal single-photon source would be one for which: a single photon can be emitted at any arbitrary time defined by the user (i.e., the source is deterministic, or “on-demand”), the probability of emitting a single photon is 100%, the probability of multiple-photon emission is 0%, subsequent emitted photons are indistinguishable, and the repetition rate is arbitrarily fast (limited only by the temporal duration of the single-photon pulses, perhaps),” see [40].

Although in literature one may read about single photon sources, this is merely a terminological trick. There is a fundamental limit of “single photonity”: if the temperature is higher than zero (Kelvin), then in principle a black body which is always present in the experimental setup can radiate a photon in the prepared mode. In optics such a probability (for the room temperature) is very small, but it is, nevertheless, nonzero. To the most part, getting a real on-demand source that would produce an appreciable amount of photons is hard. On-demand sources that are readily available suffer from low single photon purity, with  $g^{(2)}(0) = 0.07$ . Some heroic efforts have led to lower  $g^{(2)}(0)$ , but these sources are too dim, hard to align and keep aligned, etc.

Nowadays, it is quite common to refer as a “single photon source” to a source such that  $g^{(2)}(0) < 0.5$ . Such an approach, namely, usage of the coefficient of second order coherence to determine whether a source is of the single photon type and then, for such sources, to measure the same coefficient to establish the operational notion of photon, is definitely based on the argument of the *circular type* – this is a consequence of the irreducible self-inconsistency of the quantum theoretic terms, at least of quantum optics.

We can, finally, say that: *One has to be well aware that the expression “a single photon source” is simply jargon used by experimenters. Unfortunately, by the theoretical part of the quantum community this expression was taken too straightforward. The usage of the coefficient of second order coherence for the operational definition of a single photon source (although acceptable op-*



erationally) is totally unacceptable foundationally. The experimental groups working on problems related to foundations of quantum optics have to put new efforts to create much better approximations to single photon sources. Finally, clean experiments to estimate the coefficient of second order interference with such on-demand sources and TES-detectors have to be performed. Such experiments are difficult to perform. And one of the psychological problems preventing to put essential efforts to such experimental studies is that there is a very common opinion that the question about the “existence of photon” has already been totally clarified. This is the wrong viewpoint. There was done only the easiest part of experimental studies, by using bad sources and bad detectors, which can be considered as only a preparatory stage for future real foundational studies in experimental quantum optics.

## 8 Non-objectivity from the viewpoint of performativity

Let us recall that the Kolmogorov’s main assumption in probability theory is that there exists a set partition into disjoint subsets and, respectively, the probability measure defined on the given set is calculated as the addition of appropriate probabilities defined on subsets. However, we have just exemplified in the previous sections that there are observables, where the additivity for probabilities is falsified if we deal with behaviors of quanta, living organisms, etc.

The *intuition of objectivity* that has been felt by the majority of physicists since the Ancient times till now was first formulated by Aristotle. According to him, there is ‘*hypokeimenon*’ as substratum of any predicates. *Hypokeimenon* is a family of singular events or singular facts (‘atoms’ in the first meaning proposed by Democritus). For quantum physicists, *hypokeimenon* is given by smallest particles and all the world is described by predicates in relation to these particles, like that: ‘the quantum has the property  $A$ ’, ‘the complex  $B$  of quanta has properties  $A_x, A_y, A_z, \dots$ , which explore physical phenomena  $x, y, z, \dots$ , respectively’,  $\dots$ , etc. By Kolmogorov, probabilities should be involved in our reasoning just on particles (singular events) or their Boolean compositions. However, the double-slit experiment means that photons cannot be considered the Aristotelian *hypokeimenon* and there are no singular events at all.

According to Aristotle, *hypokeimenon*, the ‘first subject’, underlying things  $a, b, c, \dots$ , present an objective reality. Every underlying thing possesses unique properties. It means that  $a, b, c, \dots$  are atoms of our database. There

is nothing less than them. Due to properties, we can group atoms within different classes  $P$ ,  $Q$ ,  $R$ , ... The more general property of thing, the more extensive class to which it belongs by this property.

Hence, the idea of *hypokeimenon*, the underlying things, allowed Aristotle to build up formal databases as well-founded trees of data (i.e., these trees are finite and without cycles or loops). He started with underlying things as primary descendants of trees in constructing ontological (syllogistic) databases. Let us notice that, by Aristotle, different sciences have different syllogistic databases, because they use different means for obtaining predicates for *hypokeimenon*. The quantum physics follows this Aristotelian understanding of objectivity and differs from the Ancient physics only by different ways of creating predicates for underlying things which are understood now as smallest particles.

Syllogistic trees contain genus-species relations among items. We know that in genus-species relations we can consider a branch (a relation between a genus and species) as implication, where the top of branch (genus) is regarded as consequent of implication and the bottom of branch (species) as antecedent of implication. Then for each node of the genera-species tree, we may define an intension as all reachable genera (all higher nodes) and an extent as all reachable species (all lower nodes). It is known that the greater extent, the smaller intension and the greater intension, the smaller extent.

Thus, the first logical database was invented by Aristotle. It is designed in his syllogistics. He suggested using this database as a logical frame for different sciences. Therefore if we claim that a science is a database constructed on the basis of empirical observations by applying logical inference rules, then we can claim that the history of exact science has started since Aristotle.

Let us assume that such a database is closed under all logical operations. Then in this database the following relations take place. Let  $P$  be a property. Then there is also a property non- $P$ . Further let  $P$  be more extensive than  $Q$  (i.e. an appropriate class  $P$  is more extensive, than  $Q$ ). Then we obtain the following relations (see figure 1):

- $Q$  and non- $P$  are properties which can be together false, but they cannot be together true in relation to any atom of our database;
- $P$  and non- $Q$  are properties which can be together true, but cannot be together false in relation to any atom of our database;
- $P$  and non- $P$  are properties which cannot be together true and cannot be together false in relation to any atom of our database;

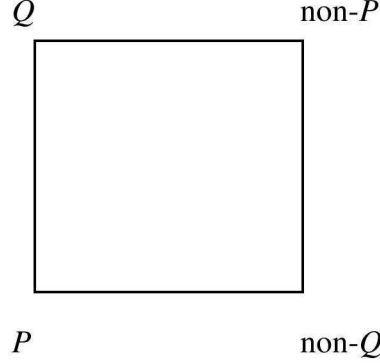


Figure 1: The Aristotelian square of oppositions.

- $Q$  and  $\text{non-}Q$  are properties which cannot be together true and cannot be together false in relation to any atom of our database;
- if  $Q$  is true in relation to some atoms of our database, then also  $P$  is true in relation to the same atoms of our database;
- if  $P$  is not true in relation to some atoms of our database, then also  $Q$  is not true in relation to the same atoms of our database.

Thus, in the Aristotelian database we deal with the Boolean algebra due to the assumption of existence of logical atoms (singular events). Since Aristotle the objectivity has been understood as a possibility to construct databases when there is ‘subject’, the underlying things, the family of atoms grouped in classes, so that these classes are closed under all logical operations. In different sciences we choose different properties of atoms and as a consequence we group atoms differently. Such an intuition of objectivity holds in quantum physics till now.

Notably, classical mechanics (CM) can be readily presented as a semantics for the Aristotelian logic closed over logical superpositions of syllogistic propositions of the following kind: “All  $S$  are  $P$ ”, “Some  $S$  are  $P$ ”, “No  $S$  are  $P$ ”, “Some  $S$  are not  $P$ ”. The point is that in CM, first, we have Aristotelian atoms or individuals defined as particles, second, in CM the state of a system  $\mathcal{S}$  consisting of  $N$  particles is defined by giving the  $3N$  position coordinates and the  $3N$  momentum coordinates. Hence, according to CM, any state of  $\mathcal{S}$  is fully determined by three values for position and three values for momentum of all particles of  $\mathcal{S}$ . These two circumstances allow us to define a verification of syllogistic propositions as follows:

**SaP:** “All particles of  $\mathcal{S}$  with positions  $S$  have momentums  $P$ ” means that the system  $\mathcal{S}$  is not empty (i.e., it contains some particles) and for all particles of  $\mathcal{S}$  if we know their position  $S$ , then we know their momentum  $P$ ;

**SiP:** “Some particles of  $\mathcal{S}$  with positions  $S$  have momentums  $P$ ” means that for some particles of the system  $\mathcal{S}$  we know their position  $S$  and we know their momentum  $P$ ;

**SeP:** “No particles of  $\mathcal{S}$  with positions  $S$  have momentums  $P$ ” means that for all particles of the system  $\mathcal{S}$  we do not know their position  $S$  or we do not know their momentum  $P$ ;

**SoP:** “Some particles of  $\mathcal{S}$  with positions  $S$  do not have momentums  $P$ ” means that all particles do not belong to the system  $\mathcal{S}$  or there are particles of  $\mathcal{S}$  such that we know their position  $S$  and we do not know their momentum  $P$ .

Formally:

$$\mathbf{SaP} := (\exists A(A \in S) \wedge \forall A(A \in S \Rightarrow A \in P)); \quad (1)$$

$$\mathbf{SiP} := \exists A(A \in S \wedge A \in P); \quad (2)$$

$$\mathbf{SeP} := \neg(\mathbf{SiP}); \quad (3)$$

$$\mathbf{SoP} := \neg(\mathbf{SaP}). \quad (4)$$

All other propositions of Aristotelian logic are defined thus: (i) each syllogistic proposition defined in (1)–(4) is a proposition, (ii) if  $X, Y$  are propositions, then  $\neg X$ ,  $\neg Y$ ,  $X \star Y$ , where  $\star \in \{\vee, \wedge, \Rightarrow\}$ , are propositions, too. Now, the Aristotelian logic can describe properties of our knowledge on systems  $\mathcal{S}$  of CM.

Nevertheless, we can assume reality without objectivity, i.e., without atoms of databases. In modern logic universes in which there are no atoms are studied as well. However, in modern sciences the intuition that logical atoms exist has been used till now, and Aristotle’s reasoning has been intuitively applied.

Notice that any context-based reasoning can be realized only in a universe without atoms. For instance, let us consider the following two propositions from the Bible: ‘bestow that money for sheep’ and ‘bestow for whatsoever thy soul desireth’ (*Deut.* 14:26). Syntactically, if we assume the existence of logical atoms, ‘bestow for whatsoever thy soul desireth’ is a universal affirmative proposition (**SaP**) and ‘bestow that money for sheep’ is a particular affirmative proposition (**SiP**), i.e., the first is more general, than the second.

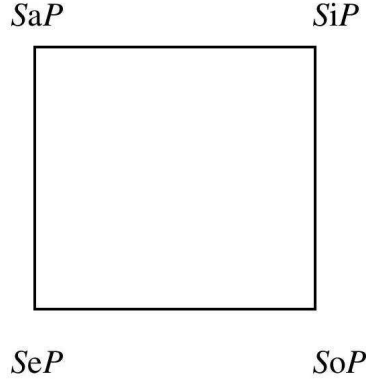


Figure 2: The unconventional square of oppositions.

However, for example, I do not desire sheep and I do not know people who desire it. Perhaps, such people exist, but I do not know. Then we cannot plot the classical square (figure 1), because ‘bestow that money for sheep’ is not included into ‘bestow for whatsoever thy soul desireth’, e.g., maybe my soul does not desire sheep, but desire many other things. The matter is that ‘thy soul desireth’ is a performative proposition and it has different meanings at different situations (there are no atoms for that proposition). This means that in this Biblical example the implication  $SaP \Rightarrow SiP$  is false in general case. Thence, we could assume another semantics, where  $SaP$  and  $SiP$  are different viewpoints of the same level. Therefore, at one and the same situation of utterance both statements (‘bestow for whatsoever thy soul desireth’,  $SaP$ , and ‘bestow that money for sheep’,  $SiP$ ) may be simultaneously false, but cannot be simultaneously true. In this way we obtain the unconventional square of opposition (figure 2).

The same situation takes place for photons and other quanta. The logical square of figure 1 does not hold for them, because logical atoms do not exist for all situations (for the double-slit experiment when both slits are open). Let us consider the propositions ‘the photon can be detected passing through all slits’ ( $SaP$ ), ‘the photon cannot be detected passing through the slits’ ( $SeP$ ), ‘the photon can be detected passing through some slits (probably through the one slit)’ ( $SiP$ ), ‘the photon cannot be detected passing through some slits (probably through the one slit)’ ( $SoP$ ). If it is possible to say that the following implication is valid: if ‘the photon can be detected passing through all slits’, then ‘the photon can be detected passing through some slits (probably through the one slit)’? In other words, if the photon is a wave and described in a proposition in theoretical terms of ‘wave’, then the

same photon is a particle and described in another proposition in theoretical terms of ‘particle’? Rather there should be the disjunction:  $SaP$  or  $SiP$ . But not implication. Indeed, if  $SaP$  is true, then the photon is not a particle in common meaning, and if  $SiP$  is true, then maybe the photon is a particle in common meaning.

In QM, it is impossible to define logical atoms. Indeed, if there were logical atoms in QM, our propositions would not be performative and would not depend upon the context of quantum experiments. It means that the reality exists, but it does not correspond to the Aristotelian intuition of objectivity when the underlying things exist, i.e., any behavior is reduced to an individual behavior. Instead of this intuition, we can propose another intuition, the non-well-funded objectivity [25], when there are no logical atoms, i.e., there is no ‘first subject’ in the Aristotelian meaning. We can add that in our picture of the world there are no things themselves (*‘Dinge an sich’* in the Kantian meaning), nothing, only behavioral complexes described by self-referent performative propositions. It is a kind of idealism proposed in the linguistic solipsism of Wittgenstein and accepted by us. A similar idealistic approach was proposed by E. Husserl. He states that phenomena are nothing more than our consciousness, and pure phenomenology is the science of pure consciousness: “Natural objects, for example, must be experienced before any theorizing about them can occur. Experiencing is consciousness that intuits something and values it to be actual; experiencing is intrinsically characterized as consciousness of the natural object in question and of it as the original: there is consciousness of the original as being there ‘in person’ ” [46]. Thus, “the concept ‘phenomenon’ carries over, furthermore, to the changing modes of being conscious of something – for example, the clear and the obscure, evident and blind modes in which one and the same relation or connection, one and the same state of affairs, one and the same logical coherency, etc., can be given to consciousness” [46]. Notice that Gestalt psychology is based on these ideas of Husserl.

Thus, in non-well-founded objectivity there are no logical atoms. What does it mean? We have properties (classes)  $P, Q, R, \dots$ . Some of these classes have non-empty intersections, and some others do not. Logical atoms are classes which cannot be intersected at all, they are singletons. Their intersection is always empty. This fact can be considered the definition of logical atom. Their logical combination (disjunction, conjunction, complement) gives any class  $P, Q, R, \dots$ . Accordingly, the universe in which there are no logical atoms is universe in which the intersection of classes is not empty. Different combinations of these intersections give different contexts of performative propositions. For such a universe instead of the Aristotelian square of opposition (figure 1), another square takes place (figure 2), e.g.,

- *In the double-slit experiment with photons:*

‘The photon can be detected in all slits’ (*SaP*), ‘the photon can be detected in no slits’ (*SeP*), ‘the photon can be detected in some slits (in QM, it means, just in one)’ (*SiP*), ‘the photon cannot be detected in some slits (just in one)’ (*SoP*).
- *Formally:*
  1. *SaP* and *SiP* are properties which can be together unjustified, but they cannot be together justified in relation to any performative situation of our database;
  2. *SeP* and *SoP* are properties which can be together justified, but cannot be together unjustified in relation to any performative situation of our database;
  3. *SaP* and *SoP* are properties which cannot be together justified and cannot be together unjustified in relation to any performative situation of our database;
  4. *SeP* and *SiP* are properties which cannot be together justified and cannot be together unjustified in relation to any performative situation of our database;
  5. if *SaP* (respectively, *SiP*) is justified in relation to some performative situations of our database, then also *SeP* (respectively, *SoP*) is justified in relation to the same situations of our database<sup>8</sup>;
  6. if *SeP* (respectively, *SoP*) is not justified in relation to some performative situations of our database, then also *SaP* (respectively, *SiP*) is not justified in relation to the same situations of our database.

Notice that in our version of QL, performative propositions expressing observables are not true or false in a conventional meaning of Russellian-Tarskian semantics, but they are justified or unjustified. Really, they have a

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<sup>8</sup>We should remark that in logic, the implication does not mean a causal relation or deep semantic relationship between antecedent and consequent. For example, the sentence “2+2=4” implies that “We are born in the USSR”, because both sentences are true. In case of syllogistic, we group quantified propositions into some classes according to their truth-conditions. So, this relationship between antecedent and consequent just formally follows from our formal definitions of *SaP*, *SeP*, *SiP*, *SoP*, see (5)–(8) and their interpretations on quantum observables below. In an informal interpretation, this relationship between antecedent and consequent means that the class of events of non-detecting in both slits is largest. The class of detecting in one slit or in both slits is smallest. It directly follows from our formal definitions below.

pragmatic rather than a semantic interpretation. In the Austian semantics (also called the situation semantics), they are evaluated as successful or unsuccessful in the given situation of utterances. We use some its versions in our logic of self-referent performative propositions.

So, instead of atoms in the quantum universe we deal with performative situations, i.e., with different intersections of classes (properties) in a collective behavior. The logical theory of performative propositions was proposed in [16], [17]. In this theory we obtain non-well-founded syllogistic trees for which there cannot be underlying things (*hypokeimenon*). Thus, there is no objectivity in classical meaning. Indeed, we can always define intersections  $A \& B$  for some situations  $A$  and  $B$  such that  $A \& B$  is an infimum of  $A$  and  $B$ . Therefore there are no atoms which can be used for building trees-molecules as their superpositions. Instead of underlying things, we suppose situations that can always be intersected.

The Aristotelian logic with syllogistic propositions defined in (1)–(4) is self-inconsistent on quantum observables, although CM plays the role of semantics for this logic, as we said. Nevertheless, we can offer a non-Aristotelian system without logical atoms, where syllogistic propositions have the following meanings:

**SaP:** “All quanta of  $\mathcal{S}$  with positions  $S$  have momentums  $P$ ” means that the system  $\mathcal{S}$  is not empty (i.e., it contains some quanta) and for all experiments with quanta of  $\mathcal{S}$  their position  $S$  is absolutely uncertain for all possibilities and we know their momentum  $P$ ; *in the double-slit experiment:* the system  $\mathcal{S}$  is not empty and for all experiments with quanta of  $\mathcal{S}$  these quanta pass through both slits ( $S$ ) and their momentum has an interference picture ( $P$ );

**SiP:** “Some quanta of  $\mathcal{S}$  with positions  $S$  have momentums  $P$ ” means that for all quanta of the system  $\mathcal{S}$  we know their position  $S$  and we do not know their momentum  $P$ ; *in the double-slit experiment:* for all experiments with quanta of  $\mathcal{S}$  these quanta pass through one slit ( $S$ ) and their momentum does not have an interference picture ( $P$ );

**SeP:** “No quanta of  $\mathcal{S}$  with positions  $S$  have momentums  $P$ ” is justified iff “Some quanta of  $\mathcal{S}$  with positions  $S$  have momentums  $P$ ” is not justified;

**SoP:** “Some quanta of  $\mathcal{S}$  with positions  $S$  do not have momentums  $P$ ” is justified iff “All quanta of  $\mathcal{S}$  with positions  $S$  have momentums  $P$ ” is not justified.



Formally:

$$\mathbf{SaP} := (\exists A(A\varepsilon S) \wedge \forall A(A\varepsilon S \wedge A\varepsilon P)); \quad (5)$$

$$\mathbf{SiP} := \forall A(\neg(A\varepsilon S) \wedge \neg(A\varepsilon P)); \quad (6)$$

$$\mathbf{SeP} := \neg(\mathbf{SiP}); \quad (7)$$

$$\mathbf{SoP} := \neg(\mathbf{SaP}). \quad (8)$$

All other propositions of non-Aristotelian quantum logic are defined as follows: (i) each syllogistic proposition defined in (5)–(8) is a proposition, (ii) if  $X, Y$  are propositions, then  $\neg X$ ,  $\neg Y$ ,  $X \star Y$ , where  $\star \in \{\vee, \wedge, \Rightarrow\}$ , are propositions, also. This non-Aristotelian logic is a very simple version of QL without logical atoms. All its propositions are performative and depend upon contexts.

Hence, we could claim that: *From the viewpoint of performativity and logical theories studying performative propositions, there is no objective reality in the classical (Aristotelian) meaning. In QM, scientists try to appeal to the objective reality with logical atoms of quantum systems, which causes self-inconsistencies. Therefore, the only outcome is in appealing to non-well-founded reality [25] and performative propositions in QM. Self-inconsistency occurs only in cases of applying classical logic and classical semantics. In our logic, there are no contradictions. The same situation is in the so-called para-consistent logics, where there are contradictions as new truth-values. Self-inconsistency is just in that we avoid logical atoms and even contrary statements in the classical logic may have non-empty intersections in our new semantics. Thus, the term self-inconsistency only concerns logical properties of our version of QL and not phenomena. Evidently, phenomena themselves simply occur and cannot be self-inconsistent.*

## 9 Existence of photon from the viewpoint of heralded photons

Due to applications of ideas of performativity in QM to the problems of single photon on demand source (low coefficient of second order coherence, high brightness, experimental feasibility, etc.), it is possible to propose a workable solution consisted in *heralded photon sources*, i.e., sources based on parametric down-conversion. These sources produce low levels of classical light in each of the two conjugated modes, but have a property that *photons are created in pairs*: one per conjugated mode, therefore detecting one photon in one mode means that a photon in the other was created with 100% certainty. In good experiments it is possible to collect up to 70% of these heralded

photons. We therefore write that conditional  $P(\text{detection}_1|\text{emission}_2) = 0.7$ , where 1,2 are the mode numbers. Similarly,  $g_{\text{conditional}}^{(2)}(0) = 0.01$ .

One can think of such a source as a source of pulsed “single photons”, where one learns about the presence of a good single photon (with  $P_{\text{register}} = 0.7$  per pulse) by seeing a click in the other mode. Most of experimenters use these sources and call them single photon sources. This substitution may be justified from the operational viewpoint, but it makes a big difference from the foundational viewpoint.

From the viewpoint of self-(in)consistency analysis of quantum physical entities, by using heralded photon sources, the experimenters try to minimize self-inconsistency by considering conditioned events. This is the crucial departure from the original event structure of the quantum formalism which is based on the assumption of the existence of individual quantum systems and uses the event algebra (in fact, Boolean) to describe measurements of a single observable on such systems. Moreover, 30% of unused pairs also destroys consistency of the event structure of the yes-no experiments, i.e., we can claim that there is no Aristotelian objectivity with logical atoms.

Finally, we emphasize that, although the value  $g_{\text{conditional}}^{(2)} = 0.01$  is relatively small, the number of coincidence clicks is still non-negligible. Hence, we can repeat considerations of section 6 and derive non-objectivity of photonic observables from self-inconsistency of theoretic entities on observables. Here, the probability of coincidence also has nonzero low bound which, of course, depends on the experimental setup. It depends on so many “technicalities” that its calculation is really a nontrivial task. First and foremost, one needs to know the number of pairs generated per second. One can expect that  $g^{(2)}(0)$  is higher for brighter states, and lower for dimmer states. Losses in both heralding and experimental channel are also important as well as properties of down-conversion. If one operates with a single mode source, the noise photons would have thermal, and not Poisson statistics. If one had a low mode number, statistics would be a finite sum of thermal states, and if one had infinite number of modes (broad background), then the background would become Poissonian. Hence a  $g^{(2)}(0)$ -value would range by a factor of 2 (single mode thermal state vs pure Poisson) for the same  $\mu$ , where the latter is the average number of photons per pulse. And – sure enough – in the presence of technicalities, such as loss, jitter and uncorrelated noise, exposure time (time window) would matter.

## 10 Self-inconsistency of dichotomous quantum observables in the light of random field model of quantum phenomena

It is obvious that one can ignore our analysis of self-consistency of quantum phenomena by regarding the problem of the coincidence clicks as a purely technical problem of the elimination of noise, i.e., having no fundamental value. This problem can have a fundamental value only under the assumption that this problem cannot in principle be solved by improving technologies for “single photon” sources and detectors. Such an assumption cannot be justified within QM. However, there are some logical reasons supporting this assumption (sections 7, 8). In particular, one can present some motivations for it by going beyond the quantum formalism and considering prequantum (classical probabilistic) models reproducing quantum probabilities. The first reaction to such a comment would be that, as a consequence of various no-go theorems, such prequantum models do not exist or if they exist, they have to be nonlocal as, e.g., Bohmian mechanics. According to Einstein, we reject such an ambiguous notion as nonlocal realism. Therefore, we discuss only local prequantum models. Of course, such models have to be nonrealistic in the Bell’s sense, i.e., non-objective in our terminology. We remark that Bell’s terminology “realism” in connection to the problem of hidden variables is a bit ambiguous. He definitely discusses realism of quantum observables expressed in terms of hidden variables. However, realism can be recovered on the level of hidden variables, if quantum observables are not expressible in terms of such additional variables. The notion of (non)objectivity is related only to quantum observables.

Thus, we want to discuss a non-objective model with hidden variables. The key point is that such a model will be self-inconsistent at the level of measurements formulated in the yes-no logics and the Aristotelian hypothesis of objectivity constructed on logical atoms. In spite such features as non-objectivity and self-referentiality which are “pathological” in classical world, our model is very natural. In fact, there is nothing more natural if one wants to arrive to quantum physics by departing from classical theory. Non-objectivity in the Aristotelian meaning and self-referentiality on the level of observations are strange only for classical mechanics of *particles*. And we consider waves, instead of particles. This approach was originally explored by Schrödinger, but later he gave up. We were able to resolve the problems which pressed Schrödinger to accept the probabilistic interpretation of the wave function (due to Max Born); in particular, the problem of the wave modelling of composite systems.

In short, in our model which is known under the name *prequantum classical statistical field theory* (PCSFT) [53]–[61] quantum systems are symbolic representations of classical random fields fluctuating at time and space scales which are essentially finer than quantum labs scales. Such fields by interacting with detectors of the *threshold type* produce clicks. These clicks are interpreted as quantum events.

In PCSFT, the irradiance of a beam of light is only an indication of its average state. If we could magnify local states, we should see a little bit of chaos. At some points, the amplitude of the waves is well below the average, and at others we get arbitrarily high spikes. In short, the field is “clumpy” at the microscopic level.

Suppose that we have a point-like detector. When the field crosses the plane of detection, it might happen that the local amplitude is close to average or lower. No detection is possible. It can also happen that we have an amplitude spike followed by several small crests. Again, the signal does not accumulate above the threshold and nothing happens. Yet, there is a real probability that an amplitude spike will continue over several cycles. In this case, sustained resonance above the threshold will result in a detection click. Consequently, the pattern of detection is produced by the low probability of transient “spikes” in a continuous field. It is not true that we have single discrete entities at the moment and point of detection.

At the level of such events, PCSFT is fundamentally self-inconsistent. The probability of a coincidence click, i.e., matching of two trains of spikes (at the micro-scale) at two detectors is nonzero, even theoretically. It decreases with increase of the threshold, but even for very high threshold a random field can produce matching spikes.

Moreover, one cannot violate Bell’s inequality and more generally to represent quantum compound systems in entangled states by considering random fields propagating in vacuum (at least in our model). One has to consider a random *background field* which is present everywhere (one may call it zero point field or vacuum fluctuations). This (classical) field contributes into correlations and, in particular, its presence gives a possibility to violate Bell’s inequality. This field has the random structure which similar to the one of random fields-signals representing quantum systems. Hence, a threshold detector “eats” energy of combined spikes, signals combined with the background field.

Non-objectivity of such observables on random fields is a consequence of self-referentiality, the impossibility in general to assign say polarization up or down. As a consequence of the presence of the random background field contributing irreducibly into threshold detection, the coincidence clicks appear irrespectively to our manipulations with random field-signals representing

quantum systems.

## 11 Conclusion

Following Bohr, von Weizsäcker, Brukner, and Zeilinger, we have analyzed the problem of inconsistency between classical language description of theoretical quantum phenomena based on Aristotelian-Russellian logics and experimental structure of these phenomena which is exhibited first of all in the complementary structure of quantum experiments (so-called “wave-particle duality”). We have presented this problem in very general context of linguistic solipsism (Wittgenstein, Searle, and Austin) by emphasizing the role of performative propositions in scientific theories and, in particular, in QM. Such propositions are in general self-referent; attempts to use them in combination with Aristotelian-Russellian logics leads to inconsistency. We have argued that, nevertheless, it is possible to escape logical self-inconsistency of quantum performativity by appealing to the approach based on non-well-founded reality [25] (as opposed to the approach based on the objective reality).

In this paper, we pointed out that the problem of self-inconsistency of QM is even deeper than self-inconsistency implied by the principle of complementarity. The latter (see presentation of views of Brukner and Zeilinger in the Introduction) implies that, for a quantum system  $S$ , it is impossible to assign consistently the truth values to all propositions about this systems. We found that even the statement about existence of a quantum system cannot be peacefully embedded in Aristotelian-Russellian logics. Our argument is based on the analysis of the experiment on “photon existence”, measurement of the coefficient of second order coherence. If positivity of this coefficient for experiments with the “single photon state” is interpreted as a foundational issue (and not just as a problem of noise and the state preparation), then the operational definition of photon as detector’s click leads to self-inconsistency of QM, self-inconsistency of coupling between the notions of QM as a theoretical formalism and the real experimental situation.

We also stressed the similarity between quantum mechanical and biological phenomena. Both are characterized by descriptions based on performative propositions and they are self-inconsistent in the framework of Aristotelian-Russellian logics. Our discussion on biological systems is restricted to performativity related to the principle of complementarity, impossibility to assign consistently the truth values to all propositions about actions of a biological system.

An important part of our consideration was about the role of experi-

menter's free will in resolving (at least partially) self-inconsistency of QM; we have pointed to the performative nature of statements related to “experimental technicalities” such as, e.g., the discrimination threshold and time window. We have also analyzed the possibility to resolve self-inconsistency of QM by going “beyond quantum”. So, we have considered a model of the classical field type reproducing the basic predictions of QM, the so-called prequantum classical statistical field theory (PCSFT). By PCSFT objectives, reality can be recovered at the subquantum level, in spite of non-objectivity of “reality at the quantum level.”

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